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The rationale of development practices for expert systems : an empirical investigation

Author
Beuschel, Werner

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The Rationale of Development Practices for Expert Systems - An Empirical Investigation -

Werner Beuschel

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Abstract: Practices of expert system development are not widely investigated. In this paper I describe results of case studies on the in-house deployment of small expert systems in two companies, along with a review of empirical research. The investigation focuses on the underlying rationale of the observed practices during the stages of design, field transfer and use. The examples show the importance of integrative approaches to technical **and** organizational aspects of development projects. The remaining potential for organizational turbulences is explained with inherent tensions of the rationale.

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Though AI and computers are often assigned a function to enhance creativity and the transition to a post-industrial culture, the phenomena ... seem to be only an extension of the serial production which characterizes the industrial culture.
(Negrotti 90:6)

1. Introduction

It is increasingly acknowledged that information system design is not only a matter of technology alone but also one of the context in which development takes place. The system being designed and its organizational context must be seen as interacting with each other, not as separate entities. To understand the results of system developments we therefore have to focus on the process, not just on the product (cf. Floyd 87). During the process of development technical and organizational aspects continually influence each other. Companies taking on system development are forced to deal with this interaction. They thereby create their own practices.

Through the analysis of practices we may gain insights into characteristics of the development process. This should contribute to our understanding of design procedures as well as to an assessment of impacts. The interactive perspective appears all the more valid for expert systems, as the necessities of soliciting, structuring and representing heuristic knowledge in many cases involve persons from other than the traditional programming departments from early on (cf. Mumford a. McDonald 89).

Therefore it was the goal of the two case studies reported here to investigate how companies actually approach expert systems development, not aimed at merely research or educational purposes. Practices are understood here as the set of strategies, activities and explicit reasoning applied during systems development with regard to technical, organizational and human factors. The analysis of the cases uncovers the underlying rationale in the practices and shows advantages and obstacles encountered during the development processes.

The cases were chosen from areas supposed to be characteristic rather than esoteric, namely applications in offices, production and maintenance areas. In-house developments were selected, since the interaction aspect of technology and organization can be expected to be more diverse than with systems bought from the shelf.

Methodology

Expert systems are a special type of interactive software. To deal with them from an empirical perspective, both aspects of this definition must be observed,

the features making them special and their relationship to the general development of information technology.

With the growing distribution of information technology beyond its former confinement in data processing centers the insight grew that the social aspects of system development processes become more important. Decisions in the course of these processes are neither just a matter of strategic choices of the management, nor of the capabilities of the technology alone. Rather it is the 'web' of organizational setting, technology and social factors, underlying the development process of computerization (Kling a. Scacchi 82). Expert systems as part of information technology therefore are amenable to a variety of functional and organizational design solutions, facilitating augmenting as well as automating approaches (Beuschel 91). Therefore, the focus of the study was not on a pre-post-statement of changes, but to understand the interaction of organizational, technical and human aspects of the development process and its consequences.

From the viewpoint of their special features, no simple, undisputed definition of what an expert system is exists. In the context of this paper they are seen as a specific type of interactive systems, aimed at the reification of decision-making processes. For the purpose of an empirical investigation it seems appropriate to state selection criteria more precisely. Two required features for selection were added, since expert systems are introduced into work procedures where cognitive processes are involved: a distinct knowledge acquisition process during the course of the development process and the existence of a separate knowledge or rule base as part of the system infrastructure.

A research approach using qualitative case studies has the advantage of in-depth explorations of issues. The studies retrospectively followed the way how a development process emerged within a company. Depending on the operational status of a system three main stages of the process were assumed, design, field transfer and operational use.

The cases were selected according to criteria of variance and relevance. This means, they should come from different industrial sectors to allow for a broader picture of determinants in applications and they should appear important enough that the conditions could be extended to similar task environments or businesses within the same sector.

Review of Empirical Research

Much of the research literature about AI and expert systems was concerned with theoretical or normative methods, neglecting empirical studies. Organizational aspects were mainly understood as the topics of adequateness of application areas, or of the management of critical events in projects (cf. Bobrow et al. 86). Now, as expert systems are slowly drifting away from elite applications, gaining more practical relevance, it still can be claimed for expert systems that "job and

organizational design issues are rarely addressed in the literature" (Östberg 88: 169).

Another reason for the lack of empirical research might be that compared to other systems the diffusion of expert systems in industry and service is still low. Many of the developments are experimental prototypes or feasability studies, and the technical capabilities of systems are still under development[1]. Due to many unjustified 'myths' and 'legends' about technical capabilities (Fox 90), their diffusion process was slower than predicted, and only in the recent years the field gained momentum (Leonard-Barton and Sviokla 88). The lack of systems in operation also accounts for the lack of quantitatively representative studies, even in countries with otherwise strong research and development activities[2].

On the other hand, most available in-depth studies do not focus on practices as defined above. They are either devoted to large and demanding development projects, which draw on large resources of budget and time and are combined with prolonged development periods and extended research status. Or, they do not put much attention on practices of design or use. But large and complex systems represent the exemption rather than the rule so far. More typical for the kind of development activities being taken on now in many companies seem to be types of 'medium' or 'low road' systems. They make use of available symbol processing capabilities of computers. 'High road' systems in contrast would require the inclusion of deep knowledge (the terms were coined by John Seeley Brown 86).

Available studies nevertheless describe important dimensions of research and their previous experiences might point to generalizable problem issues and explanations.

Enid Mumford and Bruce MacDonald (89), in an extensive case study where they both played also an active role, analyze the development of one of the most frequently cited expert systems, XSEL of the Digital Equipment Corporation. The authors depict the development process of eight years as an 'ongoing journey', showing the many requirement definition changes being made. According to their experience the organizational implementation proved to be much more difficult than the technical design. The analysis focuses on how over the years business strategies, management attitudes, group structures and expectations constitute a changing 'task environment' and thereby influence the task of design itself. The study pleads for the necessity of participative design approaches and shows the difficulties of transferring the system from US offices to European offices, mainly due to a later user involvement. While the book covers the intricacies of development processes quite vividly, it does not put so much attention on questions of the system's future life cycle. It should be noted that about 30 people were required to maintain XSEL (Coy and Bonsiepen 91) at last, and that its huge knowledge base of more than 10.000 rules is at a limit of becoming 'unmaintainable' (Östberg 88).

Several explorative studies were carried out by two groups within the framework of a technology assessment project by the International Labour Organisation (ILO) in Geneva on the impact of expert systems on work organization and skills (cf. Bernold and Hillenkamp 89). Kornwachs and Bullinger (89) investigated two systems in Germany and state the somewhat contradictory diversity of impacts, encorporating for instance up- and deskilling effects. They emphasize a picture of stepwise integration of expert systems into conventional systems, providing an advantage to those companies with already highly developed information technology. The cases show that protocolling functions are facilitated by an expert system used as part of a network, rendering the basis for centralized control. One case points to the job enrichment opportunity for a machine operator, thereby possibly changing extra-departmental boundaries. Senker et al. (89) in their study of three British systems confirm these findings. They state that expert systems extend work areas amenable to automation but they do not expect them to have unique impacts, compared with information technology development in general.

Sviokla (86) investigated three commercial expert systems in use from the vantage point of strategic advantages for a company. His socio-economic approach shows how task procedures of people become more rigid by using expert systems for previously ill-structured problems, while organizational structures are adapted. Strategic advantages gained by this 'progressive structuring' are claimed, but the study fails to relate them unambiguously to the use of the systems in question, since the interaction with the organizational changes is not analyzed.

Wieckert (90) shows in a case study of a research and development project in an aerospace company how the original goal of replacing an experienced electrician is changed during several iteration stages to the more modest goal of a support system for a maintenance engineer, while the system is still considered a success by the company. Her field study exemplifies the stepwise requirement degradations as a failure to capture the craftsman's bodily skills, his physical and spatial knowledge, and his 'deep' knowledge about the domain. The author's socio-historical analysis suggests that these mismatches are owed to the difference between ideals of expertise and knowledge -- conveyed by AI-theory -- and the requirements of everyday practice. To explain why the system after plenty of changes is still considered successful, she offers the view that expert system development does not emulate the expertise of individuals, but rather creates an entry into the work process (a perspective also taken by Östberg 88). The intervention allows for negotiating a match between system design and work needs, the developers drawing either on the expert's direct participation or on aspects of practices at his work setting. The organizational setting in this way acts as a prerequisite as well as a result of the development process, in which conflicts and negotiated solutions take place.

Summarizing, the studies confirm the possible variety of design solutions when expert systems are embedded into a organizational structure. Mumford's as well

as Wieckert's study reveal also that expert systems theory does not provide adequate means for coping with practical requirements of organizational aspects.

2. Practices in Design, Transfer and Use

Project Background

The paper describes part of my ongoing research on information technology, work organization and skills, since two years pursued with a focus on expert systems. About a dozen experts in academia and the consulting business were interviewed in order to prepare the framework for the study. The resulting guidelines and a collection of controversial issues, based on the expert talks, were used during the half-structured interviews with application experts, conducted between September '89 and March '90. Talks were led with a group manager and a developer in the first case, with a research engineer and an analyst in the latter. The interviews focused on strategies, experiences, and reasons for decisions during the main process stages. Also, system demonstrations and the analysis of printed material made available by the companies were included[3].

Very clearly, the empirical basis employed here is small and generalizations have rather the character of trend extrapolations than approved statistics. In order to escape a too narrow an explanation background, other sources were used as a corrective. These were the preceeding talks with the experts, conference reports on expert systems, and the available empirical studies.
The fictitious titles EXOFFICE and EXMAINT were chosen for the case study areas in order to establish anonymity of the participating interviewees and companies.

The cases show practices for in-house-developments of expert systems in two large companies. One case depicts procedures to initiate the development of systems in all kinds of administrative or technical offices of an established computer manufacturing company in Palo Alto. The second gives the example of a diagnostic system for maintenance support in the field production of a worldwide operating oil company, its R&D department based in Southern California.

EXOFFICE: Practices of a Computer Manufacturing Company / Technical and Clerical Offices

For obvious reasons the computer industry belongs to the earliest and most extensive users of its own products, since people are constantly encouraged and have easy computer access. This holds true also for AI-activities in the computer systems manufacturing company. A large and complex expert system was in the prototype stage to be used in wafer production of computer chips. But, according to one of the developers, it seemed to fail to represent the engineers' knowledge

to the maintenance personnel and therefore was about to be redefined as a 'training system'.

At the same time, as a rather broadly aimed activity, the company decided in 1988 to promote in-house applications of expert systems on a less demanding level. A group was installed within the information technology department, here referred to as Advanced Systems Group (ASG), with the aim of providing advising capacity on the automation of decision-oriented problems in offices. The group head was hired from within the company, with 10 years of experience in the hardware field of information technology, acquiring AI-knowledge by self-education. Both of his current collaborators in the small group were educated in computer science and cognitive psychology.

The special development strategy pursued in the latter case was to initiate the idea of introducing expert systems into the decision making of different departments. After receiving a request, ASG then essentially gave interested groups help for starting their own project. This was done by searching for appropriate applications and by providing tools. In some cases they also developed a prototype. But basically the department professionals were supposed to do their own knowledge acquisition with the help of the tools after a few start-up sessions with ASG. The rationale behind the approach was to reach "more consistency in decision making", as the ASG-manager put it, viewed as an equivalent to the idea of quality control in manufacturing.

ASG always stressed the point of keeping volume and requirements of developments low: "Use the smallest tool that solves your problem". For this purpose LISP and dedicated equipment was shunned and instead a software package used, enabling the various departments to acquire knowledge via hypertext and to model rules as decision trees. Clearly, the management goal was also to reduce skill requirements:

> "Giving people a system to make their decisions more consistent, that's a value. Empowering people to make decisions on a lower level by giving them automated assistance is another way. [The company] tends to try to manage by allowing people to make decisions at the lowest level where they have the skills and the opportunity to make the decisions because it's a more responsible environment that way. I think expert systems enable that more effectively because it allows some decisions to be made a level lower than they were made in the past, but with confidence" (Manager ASG).

In this way several initial projects were carried out, all of them but one being tested and in use since approximately fall '89. The average time for completion took about four weeks. While in these cases ASG did all the knowledge engineering, the expertise was provided by an expert at each division of the company. The systems were developed for the following problem areas:

- Troubleshooting for a software application (diagnosis problem): problems encountered by users of an internal accounting information system can be analyzed going through steps of questioning, determining if one of ten of the most general problems in the accounting system might be responsible,

- Determining required sizes of datasets (configuration problem): field personnel using a database at customer sites can, after a series of questions, determine which entry size for datasets is needed,

- Production track selection in chip manufacturing (matching problem): the sequence of manufacturing steps necessary to produce parts within given specifications is selected from a library of about 250 alternatives, according to a production worker's new part order,

- Parameter preselection in wafer production (optimization problem): the system identifies several process parameters during a production run and helps the operator optimizing test runs, putting engineer's knowledge of complex calculations in the hands of the operator,

- Performance survey in materials management/prototype (matching problem): information about aspects like quality, responsiveness and cost of commodity vendors is collected and evaluated against established qualifications, thereby maintaining a checklist for the materials department for selection of vendors.

The emphasis of the development practice was never on purely technical matters, though:

> "My experience has been that ... it's not the technical aspects of the technology, but rather the organizational and application-oriented aspects" (Manager ASG).

Despite that awareness, and despite involving intended users into design right from the beginning, several problems showed up during the different stages of development. The group manager reported that it was difficult to correct unrealistic expectations of the departments concerning a match between technical capabilities, project volumes considered 'do-able' and the available knowledge about systems. Transferring systems from the design stage to regular use was considered a critical phase. It often only then showed up whether user involvement was appropriate or not. According to some examples, user interfaces tended to be too complicated and had to be simplified with regard to their information representation and interactional procedures.

The manager saw the basic requirement for a successful fielding process primarily in the decentralized approach to AI-activities. So far, no essential

organizational conflicts occured during that phase. If a reduction of skill requirements had actually taken place it was not recognizable yet.

The main remaining question was how to maintain the topicality and conformity of rules in the knowledge base. This was apparently neglected in the beginning by developers due to easy prototyping facilities. For long-term use of expert systems it was considered essential that the knowledge base had to be adaptable to new rules without allowing several copies of a system to develop in different directions. Individual users could not be allowed to have access. To update several systems of the same type organizational procedures of access had still to be developed. A possible solution was seen in delegating this task to the original 'owner', from whom the problem being transferred to the expert system came. In this way no changes in responsibility and decision making would take place. But this issue of developing organizational infrastructure was still to be resolved in all cases.

EXMAINT: Practices of an Oil Company / Field Production Maintenance

Modelling and survey requirements motivated the use of voluminous data processing equipment in the oil industry during the past years. The potential of expert systems technology was tested from very early on. Examples of complex systems are Dipmeter Advisor, Mudman or Prospector, but the problems tackled were so severe that their use was confined to casual cases.

Like the computer manufacturer the oil company commands a large department for research and development with approximately 600 engineers and computer scientists, also supporting all needs for data processing in all branches of the company. According to the analyst, soft- and even hardware was developed among several rival groups in the research departments. But in contrast, the company did not support separate AI-groups. All of those activities were based on personal interests and efforts of the researchers, sometimes in cooperation with universities.

The investigated example reports on a system built for a much simpler and frequently noted task for expert systems -- diagnosis -- in this case of wells, a part of oil production equipment. The system is in operation since 1987 with installations at 44 sites mostly in the US, but also one installation in Canada and in Indonesia. A site can be understood as an oilfield, containing about one to two thousand wells. Work groups are made up of a foreman, responsible for half of each field, with 2 or 3 production specialists for 200-300 wells and several pumpers, each one responsible for 60-70 wells. The research engineer estimates about 100-200 production workers as the regular users of the expert system.

In the past ten years several dedicated microprocessor based systems were developed by the research engineers to be used in all areas of oil field production. The systems also made it possible to narrow the job description of

production specialists, from executing very broad tasks and responsibilities in the oil field to rather small maintenance tasks on the wells. As a (desired) consequence, personnel with lower skills had been hired since then. But afterwards there were delays in detecting and reporting maintenance problems, thereby reducing production capacity. So the idea for using an expert system was brought up by some of the research engineers. The development strategy was to use the available knowledge about the wells to build a system as part of the previously installed microcomputer system.

The system analyzes data readily available from another program. It produces a diagnostic chart containing conclusions the production people may follow or use in their own way in order to regain the full production capacity.

The development was done by the research engineers themselves since the models and rules had to make use of knowledge about oil wells only they possessed, not the production workers. A group of four engineers took part in the knowledge acquisition process, one of them the interviewee, now the group head. Due to the identity of knowledge engineers and experts in this case no problems occured during the design phase.

The transfer of the system into field use required not only a technical adaptation due to rough environmental conditions. The diagnostic output also had to be made more 'readable' for the knowledge level of production workers. So the really important issue was to keep up with errors or interpretation problems during field maintenance operations:

> "[The users] have to know that we are just a phonecall away" (Research Engineer).

This feedback opportunity was kept up over 3 years, and only at the time of the interview the system was considered error-free enough to be transferred from the R&D-department to a regular operating facility.

Since the knowledge base was not able to represent all peculiarities of the wells, long-term experience and knowledge of local production were still helpful for the production workers:

> "[The system] does not account for historical data or local operating practices. Experienced operators often have a feel for the well's behavior judging from its past production history or the performance of similar wells. [The system's] use is improved with operator experience" (Research engineer).

Training offered in a 2-day-workshop was planned and introduced from the very beginning. It was primarily technical information on using the different systems but the research engineer stressed the side-effect for class participants of better understanding the organizational context of the company. Knowledge of

procedures was necessary to enable the production specialists to report on system errors. It became clear from the training courses that it seemed easier for the production workers to accept advice from the expert system rather than from another person. They wanted to get advice on remaining questions they did not discuss during class sessions, since they did not want to show their ignorance there. The research department supported this activity, knowing that this not only would lead to feedback on system errors, but also to enhanced acceptance.

So, for the production workers it was rewarding to communicate with the research department. The output protocol of the system gave them a more tangible basis to take precautions for maintenance. However, their group heads, the foremen, weren't always convinced of diagnostics prepared with the help of the system. This gave reason to incorporate the foremen into the training plan as well. So the training course acquired an important function as a 'missing link' in the communication process between different organizational units.

3. Analysis of Development Practices

Characteristics Common to Both Cases

The applied practices led to system deployments considered as successful by the companies. Nevertheless, as the cases showed, several obstacles emerged during the different development stages of the systems. In order to find out what we could learn from these experiences we must first consider to what extent the practices are transferable.

As the description of the example settings showed, neither the task domain nor the organizational structures are unique to the cases. It is rather the confinement to small tasks what seems to restrict transferability.

Two salient strategies connect the reported cases. The first (**a**) is the use of the expert system approach for small and surveyable tasks rather than for tackling complex and large problems. The second (**b**) is the managerial emphasis put on organizational as well as on technical integration and not just the installation of a new computer system. Both strategies and their implications shall be discussed in some detail.

Ad a: In both companies the characteristics of tasks viewed to be appropriate for an expert system approach were similar. The tasks in question were part of prestructured work procedures, involving heuristic knowledge about situational or temporal circumstances and making use of more or less intensive numerical calculations in various cases. Only part of the heuristic knowledge was tried to be incorporated into the system, which may be a factor for the relatively quick and successful implementations. This differs strongly from tackling ill-structured tasks in expert system developments, which was subject of research efforts in

- Functional solutions for a task can be provided to non-experts as well as for experts

Use:

- Hands-on-experience for users is undisputable, may it be acquired by participating in the design process or by training
- Maintenance and update tasks gain importance with the number of applications
- Consistency of the knowledge base is crucial for multi-site applications, but no organizational procedures are readily available
- Developer(s) and expert(s) must be in reach until a system has gained its 'stable state'
- Non-experts may possibly increase their competency by using the new system
- Formalization of work procedures due to the introduction of an expert system allows for more precise or narrowed job descriptions
- Growing degree of formalization points to possible future forms of organizational and technical integration.

Organizational Turbulences

The two approaches to practices are to some degree different and pursue different directions concerning skill levels of users, though neither one of them so far intends to transform organizational boundaries. EXOFFICE basically relies on the users themselves. Tools, a prescriptive framework and some help in getting started are provided. This is aimed at simplifying certain decision making procedures, thereby reducing future skill requirements, and this might point to possible organizational ramifications in the future. Experts may have to take over other and more demanding tasks or they may not remain experts in future office settings of EXOFFICE. EXMAINT on the other hand provides an additional tool for users, supporting and strengthening their argumentative basis within the given organizational structure.

In order to minimize organizational friction, practices of EXOFFICE focus on involving the users from the very start, while EXMAINT tries the same by a 'hot-line' service and improved training practices. This difference can be explained with regard to the different qualificational levels of the users. While EXOFFICE has the experts themselves as users of the systems, EXMAINT provides expert (engineering) knowledge for lower skilled users. The latter example is in some way similar to an externally developed system, confronting

the user with something already designed. Unlike EXMAINT, the procedures used in EXOFFICE are aimed explicitely on reducing the skill level by simplifying certain parts of tasks. EXMAINT on the other hand wants to enhance skills which were formerly restricted, and then perceived as to be too narrow for optimal maintenance procedures.

In both cases, changes were required during the fielding phase of systems. Most importantly, the maintenance of the knowledge base not only required constant attention during development, but still remains to be resolved during regular use.

What becomes visible behind the rationale is that even small and unobtrusive expert systems require a constant focus of attention on organizational issues. This might be invoked by technical aspects (like user interfaces), human aspects (like hierarchical frictions), or organizational aspects (like available training facilities). So the question remains, to which degree this kind of integrative approach to expert systems development, as characterized above, could hope to avoid all organizational obstacles. Though integrative approaches like the ones described above can be improved gradually by learning from previous pitfalls, they are nevertheless likely to encounter non-planned events during future projects. It is in the nature of those events that they can only be dealt with during the process, not in advance.

The vivid metaphor of 'turbulences' seems appropriate to characterize the latent conflicts, becoming apparent over several isssues of the practices. One conflict emerged over understanding and correctness of maintenance procedures within the organizational hierarchy in EXMAINT. Another example is the upcoming tension between users and centralized system maintenance in EXOFFICE, based on the requirement of updating multiple knowledge bases. Resulting competency shifts may threaten other user groups and therefore lead to conflicts. In this way, both development practices inescapably create their own ambiguities, small events in the investigated cases but nevertheless potentially leading to turbulences in the organization.

One of the deeper reasons for the existence of these ambiguities in expert systems development might be due to the idealizing view embedded in knowledge theory (Wieckert 90). Emerged from the research on AI over the past three decades, it generally purveyed a rather mechanical view for knowledge as something to be simply extracted, represented, stored and distributed. Although the resulting shortcomings are also acknowledged by researchers in the field, leading to the search of 'deep' models of knowledge (e.g. Steels 89), its resonance can still be found in the practices[4]. The vast number of text books on expert systems, written in the past few years, can be seen as examples for 'intermediaries' between theory and practice. Though many of them generally point to the limits of the current hard- and software, they nevertheless freqently carry the ideal perspective of knowledge 'extraction'[5].

Evidence for the idealizing view exists also in the cases here. For instance, one of the definitions given in EXOFFICE for the advantages of an expert system describes it as "... storing valuable knowledge and later delivering it at the point of decision making". It shows the weak criteria used to characterize important features of knowledge. "Valuable" and "point of decision making" were not further defined in any sense with respect to what they might mean to organizational requirements.

The analysis of the case studies explains also why expert systems are not simply sold as a prescriptive technical package: organization, training, and interfaces have to be re-instantiated in each case, unless the most simple ones. The shortcomings are not just characteristics of the described cases, but are rooted in the underlying assumptions, as discussed. Expert systems 'to go' therefore, available from the shelf and to be applied with strict procedural rules would be simply contradictary to their basic subject, human knowledge.

4. Summary and Conclusions

The expert systems presented here in two case studies are about to fill in niches of applications, and also to become part of already existent systems and networks. Not in an imperative top-down manner as envisioned by some of the pioneers in the field, but as sort of a 'functional extension' to systems in place. This made it important to take a closer look how the technology and organizational aspects interact and how the development process is organized. Practices for design, transfer and use of small expert systems in different industrial areas were analyzed. The examples showed the emphasis put on technical and organizational integration by the developers. But despite this approach unforeseen outcomes of the development processes still occured, though on a small scale.

The paper explains this effect by showing that, regardless of precautions, the rationale contained in the development practices creates ambiguities, likely to lead to organizational turbulences. This happens mainly due to slightly shifting boundaries of competency between different groups or between users and computer. Viewed as an intervention into a work process, knowledge is re-created to be used within a new context.

The fact that the recreation as such does not become very obvious during development can be connected to an idealizing view on knowledge in the theory of expert systems. This theory covers changes in the workplace rather than making them the subject of discussion.

The important practical lesson to be learned from these and other examples is that the more human knowledge -- and not just number crunching -- is the subject of computerization, the more organizational efforts will be necessary in order to reach the goal of a usable system. The cases point to the limits of

development practices based on an idealizing theory of human knowledge. Contradicting an often heard belief, the cases also speak for the continued necessity of training efforts in the context of expert system developments.

Notes

1. Mark Fox mentioned the number of 3000 expert systems to be worldwide in test or use at a recent conference (cf. IEEE 90). This number seems low compared to sales figures e.g. of the system Windows 3.0, being already in the hundred thousands within a few month after release in 1990.

2. Reports on the diffusion of expert systems in Western industrialized countries are incomplete and presented in scattered sources. The situation in the US can only be extrapolated from examples in recent conference proceedings, since no representative studies were conducted so far. For Japan cf. Hirai 89, where some recent numbers for industrial sectors are given, showing the strong percentage of small systems.

3. An extensive report of the research study, containing the methodological framework, is available on request (in German language).

4. Needless to say that there are "many AIs" (Papert 88), not just one singular or unified 'theory of Artificial Intelligence'. But, in contrast, AI-theory here is understood as a social construction: how are popular claims, made by AI-researchers, perceived and translated by practitioners?

5. The following example appears representative for arguments presented by some textbook authors: "Knowledge acquisition is the single biggest problem in expert system development. Because knowledge is unorganized and often hidden by compiled knowledge, knowledge acquisition is a discovery process, and often the more that is discovered the more there is to learn. Whether a system contains 50 or 5,000 rules, the problems are the same, only their magnitude differ" (Laswell 89: 145). Here, a statement of the problem is followed by the more or less explicit assumption of the existence of knowledge structures common to man and machine, in this example 'knowledge clusters' in human beings equivalent to rules in machines, then the attention is quickly turned to machine capabilities.

References

Bernold, T.; Hillenkamp, U. (eds.): Expert Systems in Production and Services II. From Assessment to Action? Proceedings of the International Workshop on Expert Systems, Chicago, USA, September 13-15, 1988, Elsevier: Amsterdam 1989.

Beuschel, W.: What will impact assessment teach us about expert systems design? In: Van den Besselar et al. 91, 63-72.

Bobrow, D.G.; Mittal, S.; Stefik, M.J.: Expert Systems: Perils and Promise. Comm. of the ACM, vol. 29, no. 9 (1986): 880-894.

Brown, J.S.: The Low Road, the Middle Road and the High Road. In: Winston, P.H. and K. Prendergast (eds.): The AI Business: The Commercial Uses of Artificial Intelligence, W.H. Freeman: San Francisco 1986.

Coy, W.; Bonsiepen, L.: Expert Systems: Is There Really a Challenge to Industrial Labour? In: Van den Besselaar et al. 91, 53-61.

Fox, M.S.: AI and Expert System Myths, Legends, and Facts. IEEE Expert, vol. 5, no.1 (1990): 8-19.

Floyd, C.: Outline of a paradigm change in software engineering. In: Bjerknes, G.; P. Ehn and M. Kyng: Computers and Democracy, Avebury: Aldershot, pp. 191-209.

Hirai, Y.: Trends in the Development and Application of Expert Systems in Japan: 1986-1988. AI & Society, vol. 3, no. 4 (1989), 357-364.

IEEE (ed.): Proc. of the Sixth Conference on Artificial Intelligence Applications, CAIA-90, March 5-9, 1990, Santa Barbara/CA, vol. I+II, IEEE Computer Society Press: Los Alamitos/CA.

Kling, R.; Scacchi, W.: The Web of Computing: Computer Technology as Social Organization. Advances in Computers, vol. 21 (1982): 1-90.

Kornwachs, K.; Bullinger, H.-J.: Expert Systems - Present state and future trends: Impact on employment and skill requirements (Two German case studies), International Labour Office, ILO/FRG Project INT/86/MO3/FRG: Geneva 1989.

Laswell, L. K.: Collision: Theory vs. Reality in Expert Systems. QED Information Sciences: Wellesley/MA (2nd ed.) 1989.

Leonard-Barton, D.; Sviokla, J.: Putting Expert Systems to Work, Harvard Business Review, March-April (1988): 91-98.

Mumford, E.; MacDonald, J.B.: XSEL's progress: the continuing journey of an expert system, Wiley: New York 1989.
Östberg, O.: Applying Expert Systems Technology: Division of Labour and Division of Knowledge. In: Göranzon, B. and I. Josefson (eds.): Knowledge, Skill and Artificial Intelligence, Springer: Berlin Heidelberg 1988.

Negrotti, M.: Expert systems and sound samplers: a project for a comparative study on the concept of the artificial. IMES - Working Papers series, University of Urbino/Italy, 1990.

Papert, S.: One AI or Many? Daedalus, 117, 1 (1988), 1-15.

Senker, P.; Buckingham, J.; Townsend, J.: Working with Expert Systems: Three Case Studies. AI & Society, vol. 3, no. 2 (1989): 103-116.

Steels, L.: Components of Expertise. AI Lab Memo 89-2, Vrije Universiteit Brussel, Brussel/Belgium 1989.

Sviokla, J.J.: Planpower, XCON, and Mudman. An in-depth analysis into three commercial expert systems in use. Ph.D. dissertation, Graduate School of Business Administration, Harvard University 1986.

Van den Besselaar, P.; A. Clement and P. Järvinen (eds.): Information System, Work and Organization Design, Elsevier: Amsterdam 1991.

Wieckert, K.: The Case of the Fickle Expert System. Computers & Society, vol. 20, no. 3 (1990), Proceedings of the Conference on Computers and the Quality of Life, Sept. 13-16, 1990, Washington/DC: 54-59.